2. Integrated Land and Water Management for Controlling Land Degradation and Improving Agricultural Productivity in Northeast Thailand

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Introduction

Northeast (NE) Thailand is situated between 19^{O} to 14^{O} N latitude and 101^{O} to 106^{O} E longitude. It encompasses 17.02 million ha – roughly one-third of the entire country and is the poorest region of Thailand in terms of resources, economy and household income. Most of the region's inhabitants are small holding, low income farmers who face diverse agricultural and resource problems related to extreme environmental variability, adverse climate, poor soils and limited, often unreliable water resources.

Though NE Thailand has a monsoon climate similar to other parts of Southeast Asia, the region's geophysical characteristics create special conditions. The region has average annual rainfall of 1300 to 1400 mm, but considerable variation is found. More than 90% of the annual rainfall occurs between May and October (ie, rainy season). The western half of the region is relatively drier (1100 mm yr^{-1}) as a consequence of the rain shadow effect. In contrast, annual rainfall in the extreme northeast corner of the region is often 1800 mm. The actual amount and pattern of rainfall are often extremely erratic and unpredictable. This creates considerable risk for agricultural production, 80% of which involves rainfed cultivation.

Soils in the northeast region are generally loamy sand or sandy loam, both with low fertility and poor moisture retention capacity. Deforestation has expanded cultivable area rapidly during the 1960s. But in the process, deforestation and other practices have led to changes in the hydrologic environment, and caused widespread salinity problems, soil erosion and soil fertility deterioration. In rainfed areas, water availability is becoming one of the major constraints for increasing and sustaining productivity. Many regions of Thailand have suffered from longer than usual drought periods, higher temperatures and unusual rainfall anomalies, which have devastated rural economies in rainfed areas. Out of 76 provinces, 46 suffer from water shortage. Due to these problems, a vicious cycle of soil degradation, low yields, poverty and low investment has gripped rainfed agriculture, particularly in NE Thailand.

To address these problems several watershed management programs in Thailand have been implemented during the past two decades by various government departments and institutions. Most of the initial watershed programs by Thai Royal Irrigation Department (RID), Ministry of Agriculture and Cooperatives and Kingdom Watershed Management Program were primarily focused on increasing the availability of water for agriculture and other uses. Several other watershed programs by Agricultural Development and Research Center (ADRC) and Department of Land Development (DLD) were focused on reducing land degradation and improving soil quality. More recently, the Integrated Watershed Management Project, implemented by consortium of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the Department of Agriculture (DOA), the Department of Land Development (DLD) and Khon Kaen University (KKU), is focused more on increasing the productivity and improving livelihoods of farmers through better management of natural resources. This chapter describes the general landscape, soils, crops and socioeconomic conditions of NE Thailand, reviews the various watershed management programs in NE Thailand and discusses their approach, problems and impact on agricultural productivity and natural resources. The results of integrated watershed management implemented by the consortium of ICRISAT-DOA-KKU-DLD in NE Thailand are covered in detail.

General Background of Northeast Thailand

Landscape

Typically, northeastern physiography is a saucer-shaped plateau, bordered to the north and east by Mae Khong river, to the west by Phetchabun mountain range and to the south by Phanom-Dong-Rak mountain range. The plateau is divided into two main basins by the Phu Pan range, namely Sakon Nakon basin in the north and Khorat basin in the south. Land surfaces in association with runoff flow-directions are slightly tilted from northwest to southeast boundaries for Khorat basin, which is drained by Chi river and Mun river, and from the divider-line to northeast boundary for Sakon Nakon basin, which is drained by Song Kram river. The landscape is predominantly characterized by a gently sloping to undulating landform. The average elevation is about 170 m above mean sea level.

Soil Features and Management

Soil features: Soil in gently undulating land (nearly 80% of NE landform) is covered by Mesozoic and Paleogene Tertiary sedimentary rock formation (ADRC 1989). These soils are characterized by sandy textured top soils. A skeletal soil owing to shallow laterite layer is widespread in Sakon Nakon basin and comprises 13% of the NE. Saline and sodic soils commonly occur in the plateau and cover about 17%. The alluvial plain has fertile soil and is distributed along the Mae Khong, Chi and Mun rivers and their tributaries but it is rather small in area – only 6% of total NE area. Sandy topsoils, salt-affected soils and skeletal soils are regarded as three major problem soils in the NE region. Low soil fertility caused by these soils on the plateau and erratic rainfall are responsible for low agricultural productivity in NE Thailand.

Soil erosion and nutrient loss: Soil erosion is a major problem in degradation of natural resources. About 6.77 billion ha (40%) is affected by soil erosion. Mean annual suspended sediment transported by Mae Khong, Chi and Mun rivers is 9.39, 1.04 and 1 million t while soil loss is 0.16, 0.02 and 0.01 mm yr^{-1}, respectively. Sedimentation is secondary process after soil erosion, consequently, transported to streams or reservoirs. Soil erosion causes nutrient loss. The NE region recorded very high K loss (Table 1).

Table 1. Mean annual nutrient loss from different regions of Thailand[1].

	Nutrient loss (t yr^{-1})		
Region	Nitrogen	Phosphorus	Potassium
North	38.29	4.47	75.59
Northeast	18.90	1.21	91.64
Eastern	17.89	1.07	30.86
Southern	17.31	0.45	13.25
Total	92.4	7.2	211.3

1. Source: http://www.rid.go.th

Soil management: The ADRC in NE is a tri-parties project that involves Thailand, Japan and USA. With the main support of JICA for over the last 10 years, ADRC has played a key role as an international technology center for soil management in NE in collaboration with local Thai multi-research organizations in agricultural sciences such as DLD, DOA and KKU under the coordination of Office of Permanent Secretary (OPS). Several research inputs focused on improving problem soils (sandy, saline, erosion and skeletal) in order to increase crop production. Several types of maps such as agroecological zone map, land suitability map, saline soil map, erosion status map, groundwater and area suitable for small-scale water development map were produced. The study revealed the hypothesis of soil salinization that saline groundwater originates from rock salt that comes up through the fractual zone, silt stone aquifer becomes saline, contaminates shallow aquifer and comes up to surface during dry season. Vetiver grass (*Vetiveria zizanioides*) and ruzi grass (*Brachiaria* *ruzizensis*) planted as contour-strips are promising systems to prevent soil loss and water runoff. *Sesbania rostrata* shows high potential as a promising green manure crop for supplying both N and P in unfertile soils of NE rainfed lowland rice. Stylo (*Stylosanthes hamata*) and sunnhemp (*Crotalaria juncea*) are well suited in upland for crop rotation green manuring. Application of biofertilzers such as mycorrhiza, blue green algae and azolla enhanced the effectiveness of chemical fertilizer. Using 1.5 m wide ridge associated with 14 d at regular intervals resulted in the highest irrigation efficiency in soybean cultivation. Planting eucalyptus trees in the upper part reduced salinity of soil in lowland paddy. Some of these research findings are widely implemented in problem soils of NE (ADRC 1989).

Land development technology transfers: The DLD plays a major role in both soil improvement and soil conservation through the conventional concept of extension and technology transfer through three actors, viz, technology development process – researcher, extensionist and implementers (farmers). The mobile unit team consisting of a technical officer, driver and tractor helped farmers to build terraces on sloping land with farmers contributing their share towards petrol and food expenses. However, this approach proved to be ineffective as farmers considered it to be a government scheme and did not maintain the terraces. This is an example of common failure of public resources properties management. The information flow in one direction from researcher to extensionist and to farmers with little or no interaction seldom has good understanding of the farmers' environment and constraints of adoption. The "People-Centered" and "Farmers' Participatory" concepts are now generally accepted. The soil conservation program must work closely with land users from the initial stage. There are "Soil Doctors" also known as "Soil Doctor Volunteers" (SDV) in each Land Development Village (LDV) programs across the country. The SDVs are seemingly good actors as key local "information desk", which is empowered by DLD incentives providing through various forms, viz, cost-sharing of various on-farm conservation measures, farm inputs, job contract to produce seedlings or work on project activities, infrastructure such as village/farm road, education and vocational training, and right to making recommendation for participation of villagers in project activity. In LDV programs, total cost is paid by the government towards establishment of conservation measures, and since there is no contribution from farmers, farmers' participation in the maintenance of the structures is in question.

Crop Production and Socioeconomic Conditions

According to archaeological excavation at Ban Chiang and Udon Thani, agriculture began to be practiced over 3000 years ago. The lowland areas were first utilized for the cultivation of rice, which became the staple food of the early inhabitants. The upland area was utilized only since the last 40–50 years for additional family income. The first major upland crop was kenaf, followed by cassava in low fertility areas and maize along the fertile land tracts. Other major upland crops introduced in the area were sugarcane, cotton, groundnut, soybean, castor, mung bean and sesame. Kenaf area has experienced a continuous decline due to competition with cheaper synthetic products and marketing problems. Cotton has also rapidly decreased in planting area due to pest-control problems. Currently, even the cassava area has been slowly declining and is being replaced by sugarcane. In recent years, area under sugarcane cultivation has grown rapidly due to relocation of many sugar mills from other parts of the country. Moreover, most of these local mills have been able to increase the crushing capacity, following installation of improved equipment.

Fruit trees were slowly introduced into the cropping systems of the NE region. Commercial fruit-tree production was initiated only two decades ago and in recent years, many large plantations were established because of the availability of cheap land and labor.

The majority of the NE farmers are still dependent on the cultivation of crops. Crop income account for more than 60% of the family's total farm income, while livestock and agricultural employment contribute only about 32%. However, the off-farm income of the average NE farm family was slightly higher than the agricultural income. This fact implies that the low agricultural income is not sufficient to support the family and it has become important for NE farm families to seek employment outside farms.

The economic and social conditions of the country have changed rapidly in the past two decades. As a result, agricultural production in the NE has also been affected. Farm labor were drawn into the industrial and service sectors in other parts of the country. The NE agriculture production needs proper initiatives that would improve family income and tackle the problem of reduced-farm labor for a sustainable production system.

Water Resources Development in the Northeast

Strategy of water resources development: The water resources development strategy for the NE follows two-pronged water policy needs: first to emphasize on distribution system from existing sources of reservoir and rivers. This can be classified into three zones: Zone I comprises 0.34 million ha with 8–9% of farm families and land is irrigable by large-scale reservoir; Zone II consists of 0.31 million ha with 10% of farm families and land is irrigable by pumping from reliable rivers; and Zone III areas are meant to meet basic requirement in every village. These areas are inaccessible from reservoir and reliable rivers. This zone comprises 80% of farm families, and small-scale water resources development can only meet basic domestic water needs and minimal supplementary irrigation requirements (Table 2).

Table 2. The potential use of alternative sources for small-scale water resources projects[1].

Village use and requirement	Weirs	Rehabilitation	Village tanks	Dug ponds	Deep wells	Shallow wells	Roof runoff
Drinking					x,?	x, ?	x
Domestic	x	x	x	x	x	x	?
Animal	x	x	x	x	x	x	
Wet season crop	x	x	x	x	x, ?	?	
Dry season crop	x	x	x	x, ?	x, ?	?	
Fisheries	x	x	x	x			

1. x = Potential use; ? = Questionable.

Weirs, rehabilitation of natural streams (*Huay*), swamps (*Nhong*) and small reservoirs or village tanks are typically found in all mini watersheds of NE where common land is available for inundation. Dug-out pond or farm ponds are built by excavating the earth below the ground with some sort of seepage control method which are relatively smaller than village tanks and are usually dry in the dry season because of seepage. The deep (tube) wells are dug down to a confined aquifer, which require pumping equipment to draw water. However, in some areas, water quality is poor due to high NaCl content in water. The shallow (open) wells are usually dug manually by villagers down to the water table. And the last alternative is collection of runoff water from household roofs and quality of this water is good and suitable for drinking purpose.

Water resources development: The RID has defined the whole Kingdom's watershed into 25 main river basins. Northeast shares only three main river basins – Mae Khong, Chi and Mun. Their coverage is about one-third of watershed area and about 20% runoff drainage of the country (Table 3).

Table 3. Main river basins, drainage area, runoff and Royal Irrigation Development (RID) water resources development in Northeast Thailand[1].

Main river basins	Drainage area ('000 km^2)	Mean annual runoff (billion m^3)	RID Water Resources Development Schemes No. large & medium	No. small & others	Stock (mil. m^3)	Irrigable (mil. ha)
Kingdom	511.48	213.42	694	9362	37.75	3.106
Northeast	165.85	44.03	178	5184	6.02	0.464
Mae Khong	46.67	13.29	(Chi)	(Chi)	1.16	(Chi)
Chi	49.48	11.24	75	2025	1.79	0.198
Mun	69.70	19.50	109	3159	3.07	0.266
NE (%) share	32.4	20.6	25.7	55.4	15.9	7.035

1. Source: Consolidated from RID (http://www.rid.go.th)

Agencies involved in water resources development: Several departments under the Ministry of Agriculture and Cooperatives are responsible for various aspects of water resources development. The RID plays important roles in the development of water resources and irrigation system facilities. The major responsibilities of the RID are construction and maintenance of various sized (medium and large scale) reservoirs associated with main irrigation systems, which serve 15% irrigated area of the country and also small to second-scale schemes such as village tanks, rehabilitation of natural resources like dredging streams and swamps, levee for flood protection and supply of water through mobile water tanker during emergencies such as in drought relief program. Providing water for agricultural production is the main responsibility of RID. Accordingly, RID project sites are almost implemented in lowland of basins or wide flood plain of the rolling topography.

In sub-river basin context, which is defined as Zone III, gently sloping undulated upland, mini-watersheds are located. The DLD's major responsibility is to take up soil conservation measures and, wherever feasible, water resources projects are included as part of soil conservation measures. Small-scale water resources (SSWR) developments are focused on farm lands, farm ponds, shallow wells, dredged waterways, sediment weirs and earthen bunds. Up to 2004, DLD completed construction of 1807 structures of SSWR, which was recently specified as optional component in almost all LDVs. Similarly, the major responsibility of the Office of Land Reform is land reform and consolidation. It is also empowered to construct water resources projects as a part of agricultural land development. Recently, the OPS has launched integrated farming program under King's New Farming Theory and farm pond is a key component of pilot farms. Generally, various government programs have included farm ponds construction as priority.

The Department of Agricultural Extension (DOAE) initiated deep well pumping project as part of extension promotion program.

The Electricity Generating Authority of Thailand (EGAT) is concerned with construction of the major dams for electricity generation for domestic and multipurpose uses. Domestic water supply, irrigation and flood control facilities are closely connected. The Accelerated Rural Development (ARD), which has been now reorganized, has responsibilities of small reservoir construction, and well drillings program to provide water for basic needs in the village. The major responsibility of the Community Development Department is to take up the RID small-scale water resources project for community development. National Energy Authority (NEA) is involved in providing water for irrigation from medium- and large-scale reservoirs. The results were very promising, but unfortunately NEA is not authority in-line agency in executing this type of work.

Between the several organizations/agencies working on water resource development in NE Thailand, lack of proper coordination and budget allocation were the main problems identified. Also the responsibility of the organization in context of SSWR was not clear. These problems made the water resource development program less effective in NE Thailand. It was suggested that one of the existing dividing line between various agencies, viz, RID, ARD, CDD and DLD is by cost per project execution. These agencies normally are involved with total project cost of not less than one million baht per project.

The socioeconomic impact of three common types of SSWR of RID, typically in lowland, indicated that water availability in dry season enhanced upland crop and vegetables production (Thawilkal 1997). This can be implied that the productivity of paddy in Zone I and Zone II (20% arable) may not need much supplementary irrigation in rainy season, while it is essential during dry season. In contrast, in rolling upland of Zone III (80% arable), SSWR plays a vital role not only for rainy season paddy productivity but also to generate extra farm income through dry season crop cultivation. These findings clearly indicate that water resource development should be given high priority to sustain and increase productivity.

Integrated Watershed Development Experiences

As discussed earlier, several activities on soil improvement, land development, water resources development, crop and livestock production activities were functioning independently. An area-based problem-focused approach, with the integration of multi-disciplinary partnerships in a holistic system of management, is necessary to combat the problems. The term “watershed” refers to a sub-drainage area of a major river basin (Dixon and William 1991), whereas

“Integrated Watershed Management Approach” is the process of formulating and implementing the course of action involving natural and human resources in the watershed to achieve specific social objectives. This approach requires the linkage between the upland and lowland in both biophysical and socioeconomic aspects.

The Thai-New Zealand Small Watershed Development Project, about 10 years back, had launched a four-year program “People Volunteer’s Weirs” by using participatory approach with the construction of weirs in series on stream flows of two pilot watershed development programs in Huay Yang watershed of Bua Yai district, Nakon Rachima province and Huay Khow San watershed of Det Udom district, Ubon Ratchathani province. Experiences of pilot projects indicate that comprehensive implementation through biophysical and socioeconomic aspects were effective. The project was institutionally well organized and supported with convergence of the government development agencies of multi-agencies and participation of farmers and local stakeholder. The project’s performances were well recognized countrywide and had won awards/prizes periodically. Several training courses, seminars and meetings were organized and dissemination of information through digital maps, manuals and books were published for various stakeholders. This was found to be quite effective in project operation.

Japan International Research Center for Agricultural Sciences (JIRCAS) program on “Comprehensive Collaborative Research Project on Development of Sustainable Agricultural System in Northeast Thailand” focuses on effective utilization of local resources by a comprehensive technology improvement. Several new technologies were introduced to make the system more productive. Direct seeding paddy has resulted in labor saving, thereby giving more profitable paddy production. Forage production for feeding livestock throughout the year was also developed. Small farm machines were introduced to improve efficiency of farm operation. Leguminous tree strip planting, alley cropping, minimum tillage and plastic sheet bed for soil moisture conservation were also demonstrated.

JIRCAS has extended the project titled “Increasing Economic Option in Rainfed Agriculture in Indo-China by Efficient Use of Water Resources” for another seven years to address economic aspects of rainfed agriculture. It aims to demonstrate the promising technologies for farmers to choose. The program is being implemented in Nong Saeng watershed of Ban Had District, Khon Kaen Province. This is aimed to scale-up promising technologies developed by the previous project. During the first year of farmer participatory research, study was on “Mg white enforcement dikes technique” to replace the damaged dikes in paddy caused by upstream runoff erosion in previous rainy season. Although the downstream paddy field dikes were damaged and eroded, sediment was deposited on the fields but it was never an issue with downstream farmers, as the runoff from fertilized sugarcane fields were beneficial to paddy crop and increased yields.

Integrated Watershed Management with Holistic Approach

The concept of integrated watershed management with holistic approach for increasing agricultural productivity and enhancing people's livelihoods is relatively new in NE Thailand. In 1999, an integrated watershed management program was initiated at Tad Fa village in Phupaman district of Khon Kaen province. A new farmer participatory consortium model for efficient management of natural resources and for reducing poverty has been adopted. A consortium of institutions was formed for project implementation and technical backstopping. The DOA, DLD, KKU and ICRISAT formed a consortium for implementation and technical backstopping at two benchmark sites, viz., Tad Fa watershed in Phupaman district and Wang Chai watershed in Phuwiang district.

Tad Fa Watershed, Phupaman, Khon Kaen

Tad Fa watershed is part of a large basin of Chi river, which is located at latitude 15° 30' N and longitude 101° 30' to 140° 30' E and is about 150 km northwest of Khon Kaen. It is a junction of three big watersheds namely Chi in east, Mae Khong in the northeast, and Pasak in the southwest. Tad Fa watershed is located in two provinces. In the eastern part of the river, Tad Fa comes under Khon Kaen province, which has nearly 700 ha, while the western side comes under Petchabun province. This watershed project was carried out in the eastern part of Tad Fa watershed of Khon Kaen province. Topographically Tad Fa watershed has high to medium slopes and soils are mostly Ustults. The land use mostly comprises field crops, horticulture and vegetables. The cropping systems under rainfed condition include maize as a cash crop on high and medium slopes and upland rice on the lower slopes. The fruit trees and vegetables are usually grown close to supplementary water resources on the lower slopes. Sometimes, legumes and cereals are rotated with maize.

Out of 700 ha of land in the eastern part of Tad Fa watershed, the middle portion of the watershed called Huay Lad, which had about 200 ha of land under cultivation, was selected covering two villages – Ban Tad Fa and Ban Dong Sakran. Most of the farmers from Ban Tad Fa village had land in the northern Huay Samtada. The watershed activities were concentrated in the Huay Lad area (Dong Sakran village) for research and development work. There are 49 farm ponds in the Huay Lad. Two micro-watersheds were identified for research. One micro-watershed is "traditional". It has moderate slope and nearly 70% of land has fruit trees and in the remaining area other annual crops like maize and upland rice are grown. The other micro-watershed is "improved". It has moderate as well as steep sloping lands and mostly annual crops like maize and upland rice are grown. All the interventions are carried out in this micro-watershed. In almost 80% of this micro-watershed, "hillside ditches" are dug for soil conservation on contour. Vetiver and maize are planted along the side of "hillside ditches". Farmers are advised to plant crops like maize along the contour instead of usual up and down the slope. One automatic runoff recorder and sediment sampling system is installed at the lowest point of each micro-watershed to monitor runoff and soil loss. The area of traditional micro-watershed is 17.8 ha with four farmers while that of improved micro-watershed is 12 ha with five farmers. An automatic weather station is installed near the research area to monitor rainfall, temperature, sunshine, humidity, wind velocity and soil temperature continuously at fixed intervals of time. Soil survey of the entire Huay Lad agricultural land is done and detailed soil map and land use map is prepared. Majority of the soil is silty clay loam with a very small fraction of clay loam. Almost all the clay loam has 2–5 and 5–12% slope while a small proportion of silty clay loam has 2–5% slope and the rest has 5–12, 12–20 and even 20–35% slope. There are 13 distinct soil series and their variants in Huay Lad. Detailed baseline survey of households covering size of family, age, education, source of income, size of land holding, land use, crops grown, agricultural implements, animals reared and financial status of farmers involved in the micro-watershed has been carried out. Since the history of cultivation of these lands is only about 80 years, the soils are rich in organic matter and support reasonable crop production.

Agroclimatic Features of Tad Fa Watershed

Rainfall characters: Average annual rainfall of the watershed is about 1300 mm and average annual potential evapotranspiration (PET) is about 1435 mm. Rains generally start by March and continue up to October with above 100 mm of rainfall per month. May, August and September are the rainiest months. Total number of rainy days (receiving more than 2.4 mm per day) in a year is about 71; and more than 10 rainy days per month occur in May, August and September. Generally, there are about four days with a rainfall of more than 50 mm in the rainy season. In 2000, sixteen such events occurred while in 2001 only one event occurred. There is a large variation in rainfall amount and distribution over years and within the season. To understand the variability of rainfall in the region, long-period rainfall data of Khon Kaen was analyzed and is presented in Figure 1.

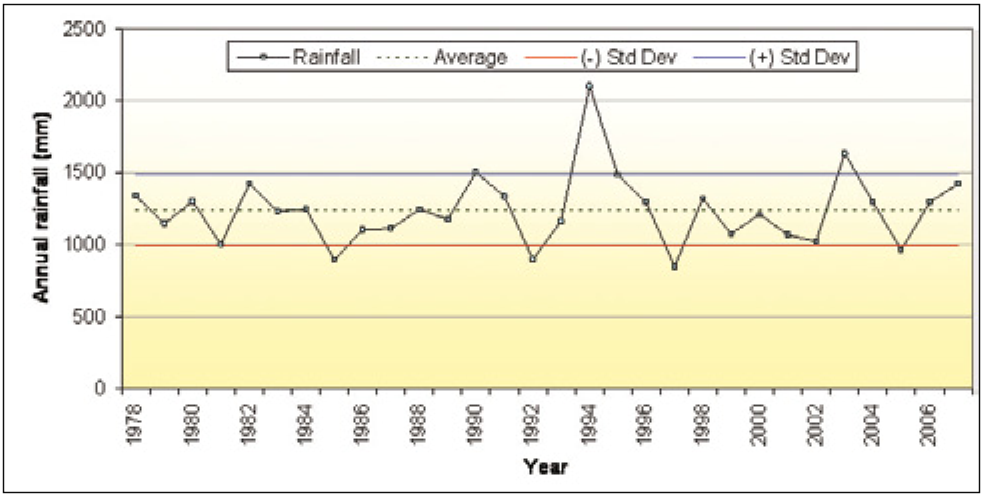

Figure 1. Variability in the annual rainfall at Khon Kaen.

Figure 1 shows that during the past 30-year period (1978–2007) at Khon Kaen, rainfall varied from about 2100 mm in 1994 to 850 mm in 1997. However, no trend in rainfall is observed. The long-period average for annual rainfall is about 1240 mm with a standard deviation of 250 mm and the coefficient of variability being 20%.

Water balance: Water balance of Tad Fa is computed based on the modified method of Thornthwaite and Mather (1955). The FAO Penman-Monteith method as described by Allen et al. (1998) is used for computing weekly PET. Figures 2 and 3 show the water balance in Tad Fa watershed for the wet year (2000) and dry year (2001) and the distribution of rainfall, PET and actual evapotranspiration (AET) over the meteorological weeks. Periods of water deficit, water surplus, soil moisture accretion and soil moisture use are also demarcated and their areas represent the quantity.

During the wet year 2000, rainfall was more than the PET, starting from the first week of April and this condition continued till the first week of November (Fig. 2). However, there were a few times when rainfall was less than PET. Soil reached its field capacity by the last week of April and water surplus started accumulating. Annual water surplus was 1240 mm. There was negligible water deficit during the rainfed crop-growing period and the annual water deficit was 352 mm. On the other hand, during the dry year (2001), rainfall was more than the PET, from the last week of April and this condition continued up to the middle of September (Fig. 3). A meager water surplus of 77 mm was observed in two weeks (not consecutive) with little prospects of water harvesting. There was considerable water deficit even in the crop-growing period and the annual

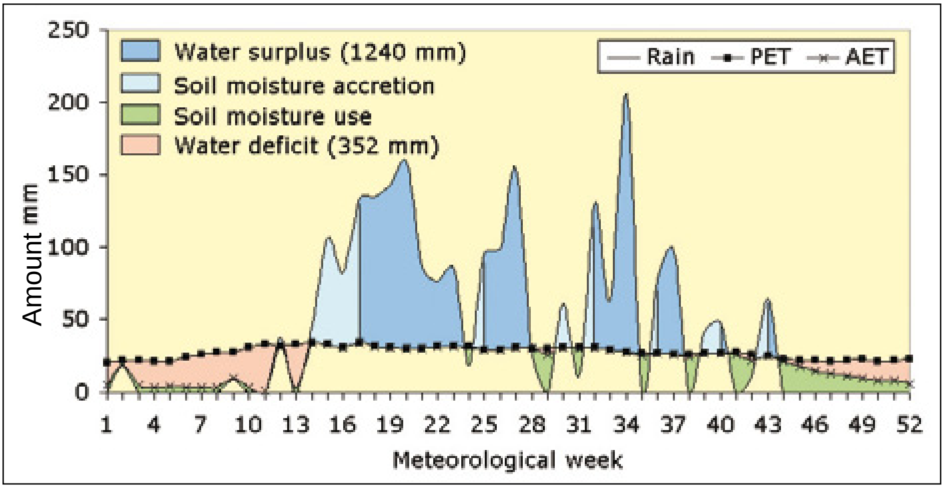

Figure 2. Water balance during wet year (2000) at Tad Fa watershed.

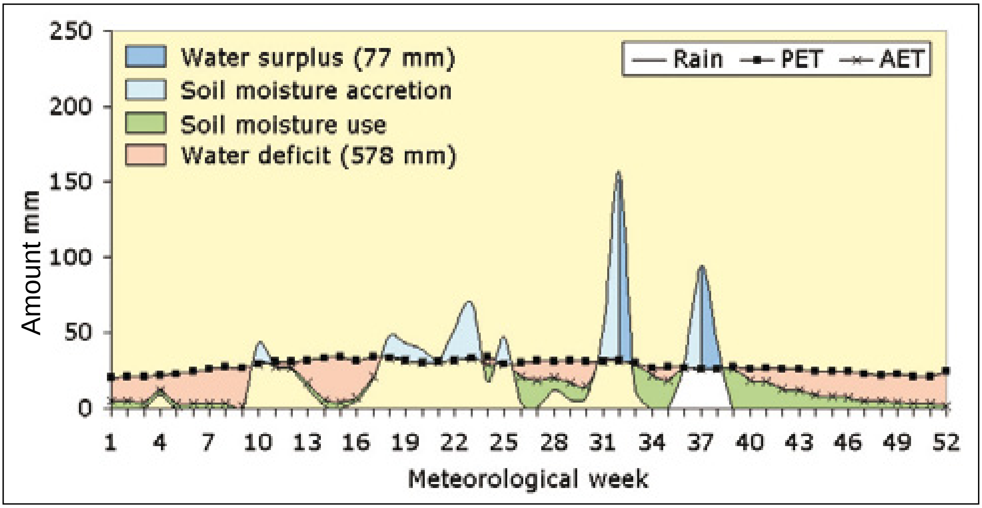

Figure 3. Water balance during dry year (2001) at Tad Fa watershed.

water deficit was 578 mm. Water balance diagrams help in understanding the distribution of various water balance elements and their interpretation helps in planning water harvesting and management of crops.

Length of growing period: Length of the rainy season is the duration between the onset and end of agriculturally significant rains. The length of growing period (LGP) is defined as the length of the rainy season, plus the period for which the soil moisture storage at the end of rainy season and the postrainy season and winter rainfall can meet the crop water needs. Therefore, LGP depends not only on the rainfall distribution but also on the type of soil, soil depth, water retention and release characteristics of the soil. This assumes greater importance from a watershed perspective where soil depth in a toposequence can also alter the LGP across the watershed – it is longer in the low-lying regions and short in the upper reaches of the watershed.

Using water balance technique, week-wise index of moisture adequacy (IMA) was computed; IWA is defined as the ratio of the actual evapotranspiration to the potential evapotranspiration and expressed as a percentage. Beginning and end of the growing season was identified based on the IMA. The growing season begins when the IMA is above 50 per cent consecutively for at least two weeks, starting from the middle of May. The end of the season is identified when the IMA falls below 25 per cent for two consecutive weeks, when seen backwards starting from the end of December.

Rainfed growing period characters for Tad Fa, as obtained from the LGP analysis, are presented in Table 4. Rainfall records were not reliable for 2004 and hence the results for 2004 were not included. Values of PET, rainfall, water surplus and water deficit are for LGP in the respective years and are not annual values.

Table 4. Rainfed growing period characterstics at Tad Fa watershed (2000–05).

Item	2000	2001	2002	2003	2005
Starting	10 Apr	10 Mar	15 May	20 Feb	20 Mar
Ending	31 Dec	20 Nov	31 Dec	10 Dec	15 Dec
Length of growing period (days)	265	255	230	293	270
PET (mm)	1088	1098	943	1246	1085
Rainfall (mm)	2253	909	1147	1806	1374
Water surplus (mm)	1240	77	333	762	379
Water deficit (mm)	105	294	199	209	225

At Tad Fa, the length of the rainfed crop-growing period varied from 230 to 290 days (Table 4). Even in the dry year (2001), the growing period was as long as 255 days due to the distribution of rainfall. Beginning is more variable compared to the end of the period. Excluding the extreme years, it is observed that about 300–500 mm of water surplus and 200 mm of water deficit are experienced during the growing period. The period from April to mid December appears to be the assured rainfed crop-growing period.

Variability in the distribution of rainfall in the crop-growing period results in dry and wet spells of varying durations. Dry and wet spells during the crop-growing season have been defined based on the IMA. When the rainfall and the soil moisture contribution put together cannot satisfy even 25 per cent of the crop requirement, the period is termed as 'very dry'. If the IMA is between 76 and 99 per cent, crops in general do not suffer from water stress and the period is termed as 'moist'. Some of the 'wet' weeks have heavy rainfall leading to accumulation of runoff for water harvesting and also to soil erosion. The classification of the different periods is as follows:

Type of spell	IMA (%)
Very dry	0 to 25
Dry	26 to 50
Semi-moist	51 to 75
Moist	76 to 99
Wet	100

Based on the above classification and using the Geographic Information System (GIS) technique, dry and wet spells at the Tad Fa watershed were delineated (Fig. 4). There is no definite relationship between the beginning and length of growing season. Droughts (more than two consecutive weeks with very dry conditions) occur often during the first half of the growing period. Severe dry conditions occurred during 14–16 meteorological weeks (first three weeks of April) in 2001. Growing period extended beyond December in 2002. This analysis helped in identifying optimum time for sowing and choosing suitable crops, varieties and cropping systems matching the moisture regime at Tad Fa.

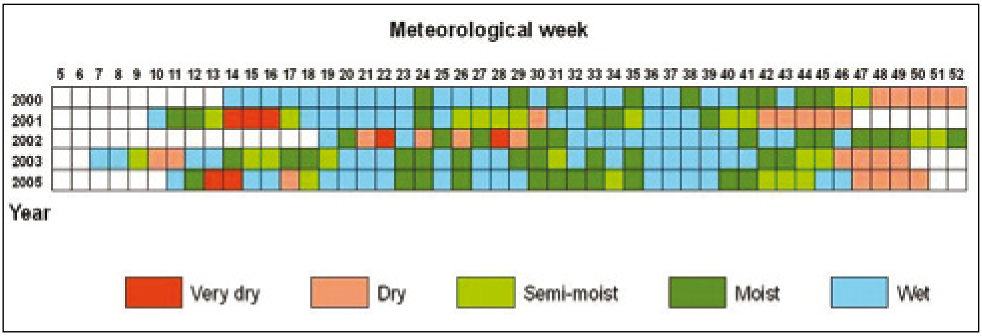

Figure 4. Dry and wet spells during growing period at Tad Fa watershed.

Socioeconomic Survey of Tad Fa Watershed

Baseline data: The survey was conducted by following participatory rural appraisal (PRA) techniques to collect socioeconomic data of the village in Tad Fa watershed. The survey was done by organizing “semi-structured interviews of farmers” at different levels, namely village level, household level, activities level and constraints identification and technology verification level. Some of the survey details are given below:

- Village level: Farm leaders in different aspects were interviewed for obtaining information on (a) land use data and history, (b) cropping systems, (c) economic data, (d) infrastructure, (e) farmer groups, (f) culture and festivals, and (g) resource flows.
- Household level: Households were grouped into three groups namely better-off, moderate and poor economic households. These groups were interviewed to collect information on (a) labor use and availability, (b) land holding, (c) cropping activity, (d) income and expenditure, and (e) decision-making at household level.
- Activity level: Information of agricultural production was gathered on the following aspects: (a) decision to grow a particular crop, (b) land preparation, (c) planting, (d) crop management, (e) harvesting, (f) transport, and (g) marketing decision-making. Data at each activity level was collected.
- Constraints identification and technology verification level: (a) Based on the analysis of data at the above three levels, the problems/constraints were listed and these were verified with the farmers; (b) causes of these problems were identified; (c) existing solutions were checked; and (d) broad preliminary technology options were suggested to farmers and their responses were gathered.

Some of the major results of the survey are given below:

Soil: The survey indicated that there are three regions/portions, based on soil quality, in the watershed. The middle portion is the most fertile while the region at the topmost as well as at the lower most is less fertile. The soil depth ranges from 0.5 to 2.0 m. The soil is sandy loam at surface and is clayey loam to loam at sub-surface.

Cropping system: In Tad Fa watershed upland rice is mainly grown for home consumption. Maize is the main cash crop. Ginger has been tried since two years by a few farmers, but it is a very risky crop due to diseases and price fluctuations. Soybean crop is grown only in poor soils or less fertile patches since more vegetative growth has been observed in the fertile lands. Very small amount of urea is mixed with rice seeds at sowing. Only maize crop is fertilized. Rice is planted in June and harvested in October. About 2.5 to 3.0 t ha^{-1} of average grain yield is obtained. Maize is often grown twice a year depending on the onset of monsoon. The first crop is grown from March to July and second crop is from July to November. Farmers apply 22:22:22 $N:P_2O_5:K_2O$ kg ha^{-1} through mixed fertilizer. They harvest 3 to 3.5 t ha^{-1} of grain yield. Ginger is grown in March–April and is harvested in December. A very heavy dose of fertilizer (90:90:90 $N:P_2O_5:K_2O$ kg ha^{-1}) of 15:15:15 is given.

Water storage structures: There are nearly 80 farm ponds in Tad Fa, of which only four store water throughout the dry season; while the others dry up. This is because the subsoil is very porous and seepage losses are very high.

Plantation of fruit trees: Farmers have planted fruit trees only around their houses and not on steep slopes as desired (and recommended) by government.

Economics: Data on households of three main types of farmer families in Tad Fa watershed was recorded (Table 5). Data on agricultural production at village level is given in Table 6.

Table 5. Household economics of three main types of farmer families in Tad Fa watershed.

Item	Better	Medium	Worse
Members (No.)	14	20	8
Laborers (No.)	10	17	4
Plots (No.)	2	9	5
Total land (ha)	7.5	16	8.5
Subsistent crop	Upland rice	Upland rice	Upland rice
Main cash crop	Maize	Maize	Maize
Other cash crops	Fruit, vegetable, sword bean	Ricebean, sunflower, ginger, sunnhemp	Sunflower
Income in 1998 (Baht)	102455	123575	91690
Expenditure in 1998 (Baht)	78728	96900	88350
Main expenditure	General agriculture/ Maize	Maize	Maize
Debt (Baht)	33500	30500	41940
Constraints	Capital labor/land size	Labor, capital, and land size	Capital, labor

Table 6. Agricultural economics of Dongsakran village in 1998.

Commodity/activity	Production area (rai)[1]	Yield (kg per rai)	Price per kg (Baht)	Total income (Baht)
Upland rice	445	300	7	934500
Maize	2000	700	3	4200000
Ginger	180	4000	2	1440000
Sunflower	200	250	15	750000
Sunnhemp	10	250	20	50000
Ricebean	30	110	8	26400
Sword bean	200	300	20	1200000
Total				8600900

1. 6.25 rai = 1 ha

Constraints: Farmers have identified the following constraints and ranked them according to priority of their immediate need to alleviate these constraints rather than on their importance for sustainable rainfed agriculture. These constraints are:

1. Land tenure: Even though farmers have been cultivating this area since 80 years, the government never recognized the villages and they were relocated seven years back and finally only one-third of the villagers have returned to resettle (five years ago). Only in December 1998, the village has once again been recognized by the government. However, the land tenure issue has not yet been settled. Because of this the farmers think permanent land tenure is the most important issue for their future.

2. Lack of capital: Since these farmers are displaced, they do not have much capital to invest. The priority of investing the capital by most farmers is as follows:

    - Education of children is given the highest priority. There is only one primary school in the village. Farmers have to send their children outside their village for high school. They also have to provide transport for their children by investing on motorbikes which again requires considerable capital.

    - Housing is given the second highest priority. Most of the farmers have very poor temporary houses after their resettlement. They try to invest in building new houses after allotting some money for education.

- Capital investment for agriculture is given third priority after meeting the above two items. Fortunately for these farmers, the land is reasonably fertile. Rice is grown as a subsistence crop without much fertilizer application. Only maize, which is grown as a cash crop, is fertilized. However, farmers have to invest a sizeable amount of money in these crops because household labor is very scarce; all operations like land preparation, sowing, weeding and harvesting are given on contract to service providers. Also, hybrid seeds of maize are expensive in addition to the costly fertilizer input. Very few farmers have tried the risky ginger crop with huge investments and most of them suffered heavy losses.

3. Lack of water resources: Since most of the soils are sandy, there are practically no water storage structures for irrigating crops. Hence, almost all crops are grown as rainfed. Sometimes either only one maize crop is grown instead of the usual two because of monsoon delay or the second crop of maize suffers due to shortage of water as a result of the early cessation of monsoon. Lack of permanent water source is a major constraint to the establishment of fruit trees on steep sloping lands.

4. Costly agricultural inputs: As already discussed not only seeds of hybrid maize and fertilizers are costly, but also almost all the farm inputs are expensive.

5. Price fluctuation: Since prices of most of the cash crops fluctuate a lot, it is really a gamble for the farmers to choose a particular crop, viz, ginger and pineapple. Often farmers incur huge losses and as such many cash crops have become risky in economic terms.

6. Lack of government support: Many farmers think that the government should increase its support since they are the recently rehabilitated farmers.

7. Lack of transport facilities: Most of the farmers are complaining about the very poor transport facilities both for people as well as to transport agricultural inputs or produce to and from nearby markets.

8. Weed problems: Farmers complain about the severe weed problem, especially the thorny *Mimosa pudica*. As labor is in short supply, farmers have to give contract to service providers to spray herbicides, eg, gramaxone.

9. Soil erosion: Even though farmers perceive this as a serious problem, especially in steep slopes, they think it is less urgent. This is because the soil in the watershed is reasonably fertile despite sizable quantum of soil erosion. Farmers also know the reasons for soil erosion (a) slope lands, (b) inappropriate plowing method, ie, plowing down-the-slope in steep sloping lands, and (c) too much deep plowing by tractor.

10. Forest fires: In order to control weeds and to remove previous season's crop residues farmers burn them on a particular day. Often the fire goes out of control and damages fruit trees and even sometimes it spreads to nearby forest area. Labor shortage is one of the main reasons why farmers resort to burning as a means for obtaining a clean field for the preparation of reasonable seedbed.

Scientists' perception: From the scientists, point-of-view soil erosion is the major problem which will certainly affect sustainable crop production in the future. Since cropping history in these lands is only 80 years, with crop intensification since only 15 years, the soil is reasonably fertile and productive. But as years go by, both soil erosion and inadequate nutrient input supply will cause a decline in soil fertility, leading to low productivity. Scientists think some of the farmers' concerns like land tenure, transport, costly inputs, price fluctuation and labor shortage are quite genuine and will affect agricultural production in due course.

Watershed Interventions

In NE Thailand, types of land degradation (eg, biological and chemical) are not fully studied. To study the effect of land degradation on crop productivity, sites in the toposequence were identified and crop yields were monitored during 1999, 2000 and 2001 (Table 7). Soil samples at these spots up to 110 cm depth were collected and analyzed for physical, chemical and biological properties (Table 8). The maize grain yield data clearly indicated the loss of productivity on steep slopes and on moderate slopes when compared to mild slopes. The clay and organic matter content at these spots indicated that precious clay and organic matter have been eroded from the steep slopes. Most of these changes have occurred in the topsoil layers which are very important for crop production.

Table 7. Maize grain yield (t ha^{-1}) across toposequence in NE Thailand during 1999–2001.

Toposequence	1999[1]	2000[1]	2001[1]
Steep (>15%)	3.1 (3)	4.5 (4)	2.1
Moderate (5–15%)	3.6 (6)	4.8 (5)	2.9
Mild (2–5%)	4.1 (2)	5.3 (4)	3.4

1. Figures in parentheses refer to the number of farmer fields at each slope.

Table 8. Biological and chemical properties of soil samples from different depths (cm) from toposequence in Ban Tad Fa watershed in NE Thailand.

Toposequence	0–10	10–20	20–30	30–50	50–70	70–90	90–110
Organic C (g kg^{-1} soil)							
Top	28	27	26	14	13	9	7
Middle	31	29	26	18	12	10	10
Lower	40	34	29	20	35	20	19
LSD = 1.15							
Total N (mg kg^{-1} soil)							
Top	2073	2085	1956	1755	1324	1249	1092
Middle	1967	1771	1785	1376	1178	1352	1012
Lower	2336	2287	1971	1563	2345	1630	1462
LSD = 621.2							
Net "N" mineralization (mg kg^{-1} soil $10d^{-1}$)							
Top	11.89	10.03	6.80	5.52	2.30	1.97	1.47
Middle	14.22	11.16	8.93	6.07	3.84	3.75	3.04
Lower	15.11	14.49	12.72	9.04	5.73	4.53	4.70
LSD = 6.034							
Microbial biomass C (mg kg^{-1} soil)							
Top	366	304	275	258	178	149	133
Middle	362	300	240	206	173	124	100
Lower	384	328	276	213	128	145	112
LSD = 86.3							
Clay content (g kg^{-1} soil)							
Top	330	350	380	330	330	0	0
Middle	390	380	430	420	370	230	0
Lower	450	450	450	490	550	550	590
LSD = 2.4							
Fine sand (g kg^{-1} soil)							
Top	90	70	70	180	140	0	0
Middle	80	80	80	130	120	160	0
Lower	60	60	60	70	60	60	40
LSD = 1.6							
Gravel (g kg^{-1} soil)							
Top	190	150	130	100	140	0	0
Middle	130	120	100	80	250	150	0
Lower	140	140	130	110	120	100	90
LSD = 1.9							

Some of the major research and development activities carried out at Tad Fa watershed are described.

Watershed development: In consultation with the farmers, the DLD has constructed about 17 farm ponds, each of 1260 m^3 capacity (Fig. 5). The technical specifications of farm ponds constructed in the watershed are shown in Figure 6.

The farm ponds provide water for much needed supplemental irrigation to crops/fruit trees/vegetables, particularly in the postrainy season. In large areas the field bunds have been constructed along with vetiver grass (Fig. 7). This is necessary for controlling soil erosion, which is one of the major problems in Tad Fa watershed. In Tad Fa watershed the annual soil loss of 40–60 t ha^{-1} is quite common.

Soil and water management: In order to reduce tillage on very steep slopes, which may trigger enhanced soil erosion, hand dibbling on steep slopes and tractor planting on contour in moderate and mild slopes were tried (Fig. 8). Minimum tillage was found effective in controlling soil erosion. During 2003–04 about 68% area was planted on contour on mild slopes. On mild slopes, cultivation has increased maize yield by 30–40% compared to conventional up and down cultivation. It also significantly reduced the soil loss.

Integrated nutrient management: Integrated nutrient management is essential for improving the agricultural productivity in NE Thailand. Results from several nutrient management trials for rice, maize and sugarcane based cropping systems have shown very promising results.

Diversified land use system: Fruit trees cultivation is being popularized in the Tad Fa watershed. This has helped in controlling soil erosion and provided better and more sustainable income to the farmers. During 2000–2001 the area under fruit tree cultivation has increased in and around Tad Fa watershed. Several new fruits and varieties have been introduced. To increase the fruit tree system productivity and the survival of fruit trees, several new systems, viz, banana intercrop with other fruit trees, mulching, inter-row water harvesting and growing annual crops along with fruit trees have been introduced (Figs. 9 and 10).

Improved crops and cropping systems: Several new crops and their varieties have been introduced in the watershed. New relay and sequential cropping systems have been identified and tested. A large number of farmers have adopted these new crops and varieties.

Empowerment of community: Empowerment of communities and individuals and the strengthening of village institutions were done through concerted

Figure 5. Farm pond at Tad Fa watershed.

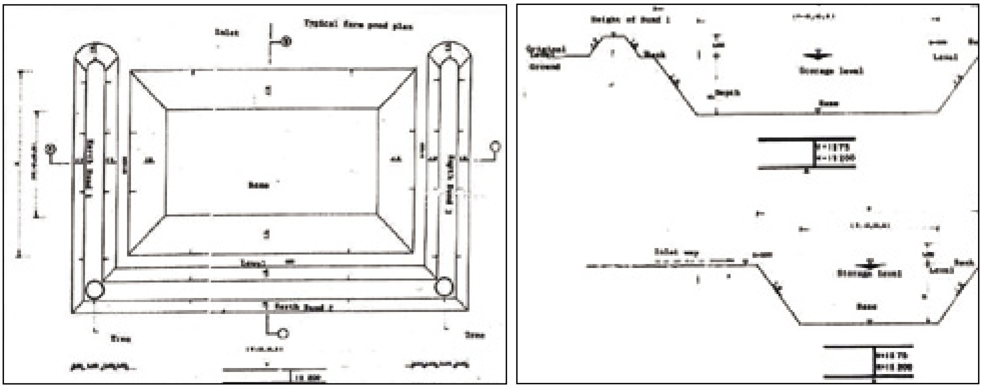

Figure 6. Technical specifications of farm pond constructed in Tad Fa watershed.

Figure 7. Vetiver hedge as field bund at Tad Fa watershed.

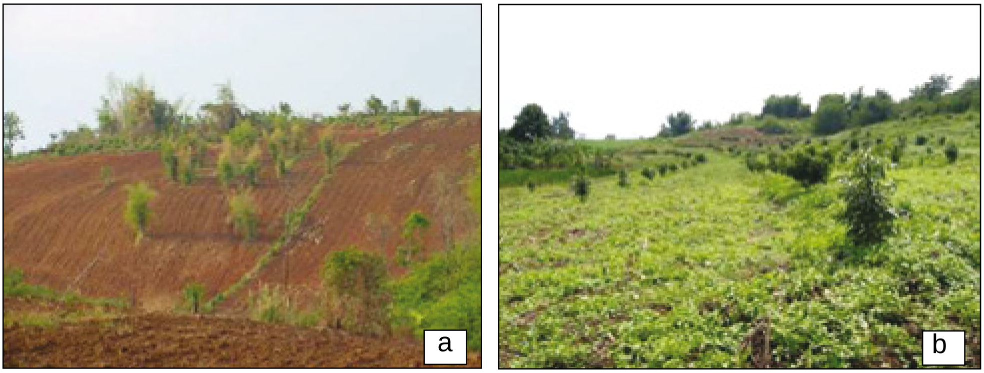

Figure 8 (a). Conventional practice (before project), and (b) contour cultivation (after project).

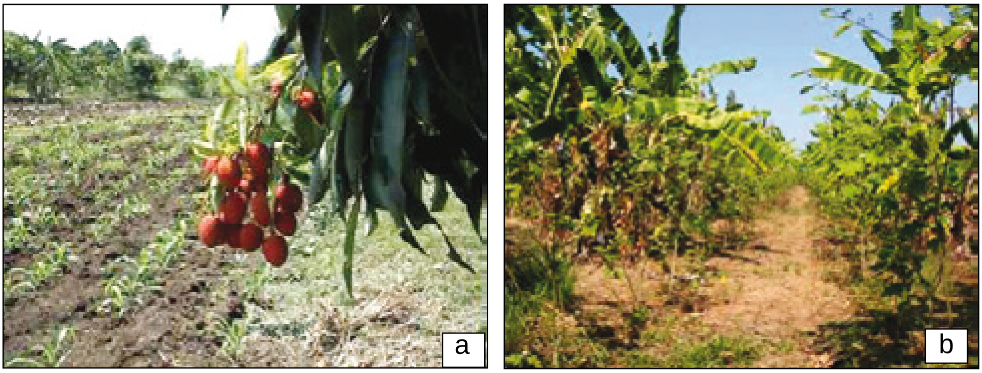

Figure 9. Cultivation of annual crops with (a) horticultural plants, and (b) banana with fruit trees as crop diversification, at Tad Fa watershed.

Figure 10. Semicircular vetiver rings around banana plants for effective soil and water conservation.

Figure 11. Hydrological monitoring system at Tad Fa watershed.

efforts. It was observed that when people are empowered to take decisions and execute the activities, they own the program. They run the watershed activities according to local, social and cultural systems.

Hydrological measurements: An automatic weather station was installed in the watershed to monitor rainfall, temperature, sunshine, humidity, wind velocity and soil temperature at fixed intervals. Two digital runoff recorders along with automatic pumping type sediment samplers were installed at two sub-watersheds to monitor the runoff and soil loss from the two land use management systems (Fig. 11). Sub-watershed-I has land under the horticultural tree-based cultivation with some areas under annual crops. Sub-watershed-II has most of the areas under annual crops and cropping systems. The mean runoff and soil loss from the two sub-watersheds during 2001–05 are shown in Table 9.

Table 9. Mean rainfall, runoff and soil loss from two watersheds at Tad Fa watershed (2001–05).

Land use systems	Rainfall (mm)	Runoff (mm)	Soil loss (t ha^{-1})
Annual crops	1725	320	34.2
Fruit trees + Annual crops	1725	131	6.1

Wang Chai Watershed, Phuwiang, Khon Kaen

Wang Chai watershed is part of Nam-Phong basin and is about 75 km northwest of Khon Kaen city. Wang Chai village is in Phuwiang district in Khon Kaen province. The mean annual rainfall is about 1000 mm. About 90 per cent of the annual rainfall occurs between May and October. Often the actual amount and pattern of rainfall are extremely erratic and unpredictable. This creates considerable risk for agricultural production since most of the watershed area is under rainfed cultivation. The soil in the watershed is mostly sandy or sandy loam with very low water-holding capacity (Table 10). The organic matter content is also very low. Major crops grown in the watershed are rice, sugarcane, cowpea and groundnut. Small areas are also under fruit trees and vegetables. The average productivity of most of the crops is quite low.

Major Research and Development Activities

Some of the major research and development activities carried at Wang Chai watershed are described.

Baseline data collection: The biophysical and socioeconomic baseline data from the Wang Chai watershed have been collected and analyzed. The major constraints for increasing the agricultural productivity were identified. The topographic, land use and soil maps have been prepared (Fig. 12). Most of the areas in the watershed have moderate to low slopes.

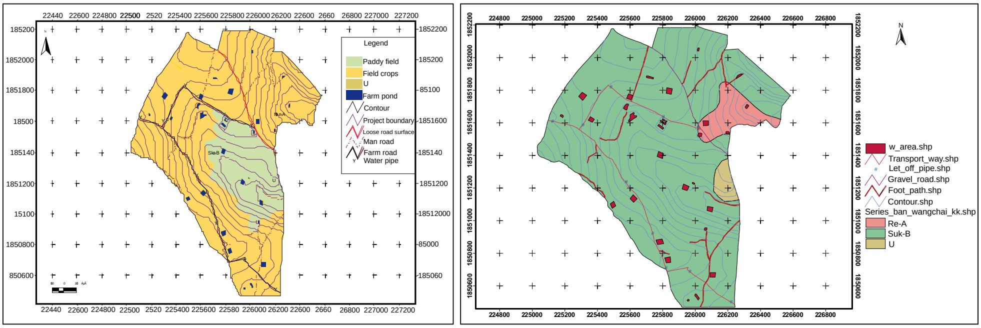

Figure 12. Topographic, soil and land use maps of Wang Chai watershed.

Table 10. Properties of the soil at Wang Chai watershed.

	Soil depth (cm)			
Parameter	0–15	15–30	30–60	60–100
Physical properties				
Sand (%)	91	92	91	89
Silt (%)	6	6	6	8
Clay (%)	3	2	3	3
Chemical properties				
pH (1:2.5 H_2O)	5.9	5.6	5.7	5.8
Organic matter (g kg^{-1} soil)	3.6	3.5	3.1	3.1
Total N (%)	0.018	0.017	0.016	0.016
Available P (mg kg^{-1} soil)	9	6	4	2
Exchangeable K (mg kg^{-1} soil)	28	22	23	35
Exchangeable Ca (mg kg^{-1} soil)	493	490	709	1307
EC (mmhos cm^{-1})	0.019	0.019	0.034	0.048

Water management and water harvesting: In consultation with the farmers, 39 farm ponds each of about 1250 m^3 storage capacity were constructed. In large areas, field bunding has been done and total 9 km village roads have been constructed. To protect the bunds and roads from erosion, vegetative barriers were planted (Fig. 13). Drains were constructed for safe disposal of excess runoff water. Rainfall, runoff and soil loss have been monitored (Fig. 14).

Figure 13. Vetiver grass planted along farm road to prevent soil erosion at Wang Chai watershed.

Figure 14. Hydrological monitoring station at Wang Chai watershed.

Crop and nutrient management and other activities: During the last two years (2003–05) various research and development activities on integrated nutrient management, water management, crops and cropping systems were taken up. Several self-help groups were formed. Farm and community based activities were initiated to enhance the agricultural productivity and income. New crops and varieties were introduced in the watershed. Village-based purification of rice seed was established. Training was given to farmers for value addition of field crop products.

Farmers are quite happy with the various watershed activities. The construction of farm ponds has significantly increased the cropping area in the postrainy season. Some of the activities have already resulted in increased agricultural productivity and income.

DLD farm ponds: DLD constructed 13 farm ponds in project sites (Table 11). Three farm ponds were monitored for water ponding and assessed for water utilization. In 2004 water ponding scales were installed for weekly water level recording. The farm road is protected with vetiver hedge made by DLD in the Wang Chai project site.

While selecting the location of farm ponds, farmers shared their views with DLD. About 82 per cent of farm ponds in paddy field were in higher terrain parts, downstream farm ponds closer to either vetiver bund-ring or upstream farm ponds in forest whereas the other upland field farm ponds were relocated and constructed as indicated in DLD planning (Table 12).

Table 11. Number of farm ponds in Wang Chai.

Location	Downstream to vetiver-ring farm road	Upstream to vetiver-ring farm road	Total
Paddy area	3	6	9
Field crop area	2	2	4
Total	5	8	13

Table 12. Number of farm ponds relocated to appropriate location.

	Downstream to vetiver-ring farm road			Upstream to vetiver-ring farm road			Total	
Location	Total	Relocated	%	Total	Relocated	%	Relocated	%
Paddy area	3	3	100	6	5	82	8	82
Field crop area	2	0	0	2	0	0	0	0
Total	5	3	60	8	5	62	8	61

Water ponding monitoring: Thirteen ponds were monitored for water ponding levels continuously on weekly basis by farm owners since 2004. Overall monthly rainfall and also overall water ponding levels in 2005 was lower than in 2004. In 2005 the trend of ponding level of farm ponds both inside and outside of vetiver-ring farm road (VRFR) was similar to that in 2004. The overall water ponding level of 5 farm ponds inside VRFR was higher than the 8 farm ponds outside. However, ponding levels of both inside and outside farm ponds have sharply dropped during mid and late rainy season. Figure 15 clearly shows the effect of VRFR on water ponding. The farm ponds located inside VRFR have consistently higher water ponding compared to the farm ponds located outside VRFR.

Groundwater monitoring: In 2006, our study on DLD farm ponds revealed that construction of farm ponds in appropriate location played an important role in increasing paddy productivity for both transplanted and direct seeding systems at Wang Chai watershed through effective utilization of stored water in the ponds. The water storage capability of the farm ponds in upland field and in upper paddy field was poor compared to the farm ponds in lower toposequence; also water ponding lasted for short duration in the former. However, water in upper paddy (outside VRFR) was used more for pumping up. Early in the season water storage was good in farm ponds located in the upper portion but very high seepage loss was recorded. The farm ponds in the upper portion were in recharge zone while those in the lower portion were in discharge zone.

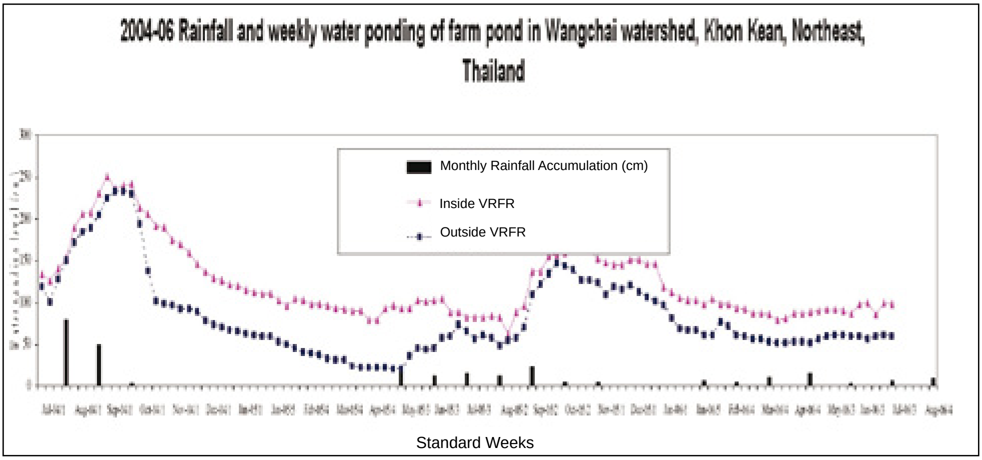

Figure 15. Water ponding of downstream farms inside vetiver-ring farm road (VRFR) and upstream ponds outside VRFR in Wang Chai watershed.

There are three farm ponds in the research site: one (FP1) located in the lower side of the valley and the other two (FP2, FP5) in the upper valley. A set of three pizometers was installed for each farm pond up to 3.5 m depth. The pizometers were placed at 10–20 m interval downward farm pond to valley. Weekly groundwater levels were measured from the end of rainy season to the next rainy season. Groundwater levels and water ponding levels of each farm pond are shown in Figure 16.

The results indicated that the farm pond water level has direct influence on groundwater level. A sharp decrease in water ponding in FP2 during the last week of October was due to the use of water for paddy at grain-filling stage. Nevertheless, it was clearly evident that the water ponding level of FP1, which is located in the foot of the valley (discharge zone), performed better than the other two farm ponds in increasing groundwater levels. The increase in groundwater availability has facilitated water application to crops as supplemental irrigation (Fig. 17).

Economics of farm ponds: A field survey was conducted to evaluate the utility and economics of farm ponds constructed with DLD and without DLD interventions. For the study, 13 DLD farm ponds and 21 other farm ponds were selected. The results revealed that the average land holding had similar number of farm ponds per household in both the cases. Most of the farmers used farm pond water for the cultivation of paddy. The income from vegetables was same in land holdings having farm ponds both with and without DLD interventions while from fruit trees, there was an increase of 36% with DLD farm ponds compared

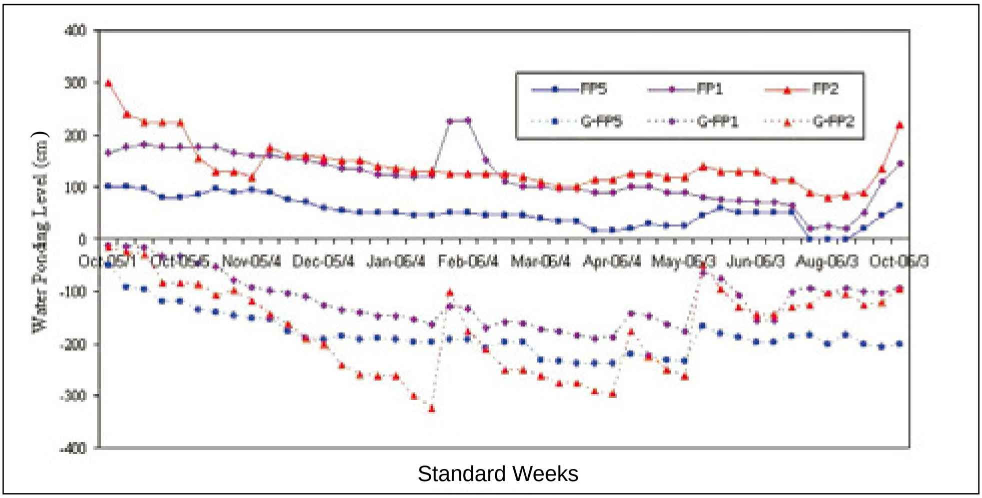

Figure 16. Water ponding of three farm ponds (FP) and surrounding groundwater (G) level during 2005–06.

Figure 17. A recharged well with pumping facility in use for irrigation at Wang Chai watershed.

to other farm ponds. The income from farm pond fishery was more than three-fold in land holdings without DLD farm ponds compared with DLD farm ponds (Table 13).

Maintenance of DLD farm ponds was better than other farm ponds. Animals were not allowed to drink water directly from DLD farm ponds unlike other farm ponds. Farmers with DLD farm ponds have paid much attention to pond water use as well as deepened the ponds to increase storage capacity for effective use of water than the group of farmers having farm ponds without DLD interventions.

Paddy productivity influenced by farm ponds: During 2004 season, paddy area with transplanting system increased in land holdings with DLD farm ponds compared to the previous season (2003). However, there was no change in land holdings while there was a drastic reduction in area with direct seeding method without DLD farm ponds.

Table 13. General information of households having farm ponds with and without DLD farm ponds in Wang Chai watershed in 2004.

Utilization and benefits	DLD farm ponds	Other farm ponds
Paddy area per household (ha)	2.7	2.4
Average no. of ponds per household	1.2	1.3
Rice as target crop (%)	100	90
Pumping use (%)	100	100
Direct returns from farm ponds		
Fish (Baht yr^{-1})	600	1,878
Vegetables (Baht yr^{-1})	706	700
Fruit trees (Baht yr^{-1})	435	591
Animal drinking (frequency)	0	187
Domestic use (frequency)	37	67
Effective utilization		
Indiscriminate use	100%	62%
Deepening of pond	38%	24%
Enlargement of pond	8%	10%

The rice cultivation area with transplanting method and paddy yield of farms with DLD farm ponds increased from 2.1 ha per household and 1.38 t ha^{-1} yield in 2003 to 2.4 ha per household and 1.54 t ha^{-1} yield in 2004 whereas farms without DLD farm ponds had rice area of 1.9 ha per household during 2003 and 2004 and increase in paddy yield from 1.39 t ha^{-1} in 2003 to 1.45 t ha^{-1} in 2004. Also rice area with direct seeding in farms with DLD farm ponds decreased from 1.4 ha to 0.8 ha but with an increase in paddy yield from 0.57 t ha^{-1} in 2003 to 1.19 t ha^{-1} in 2004. But in farms without DLD farm ponds, paddy area increased from 2.7 ha per household (0.37 t ha^{-1} yield) in 2003 to 2.9 ha per household (0.55 t ha^{-1} yield) in 2004 (Table 14). On farms with DLD farm ponds, paddy yields was five times higher (1.58 t ha^{-1}) than non-irrigated fields (0.35 t ha^{-1}) during 2004 rainy season.

Table 14. Rainy season paddy production on-farm with and without DLD farm ponds during 2003–04.

	2003		2004	
Description	DLD farm ponds	Other farm ponds	DLD farm ponds	Other farm ponds
Area (ha)				
Transplanting	2.1	1.9	2.4	1.9
Direct Seeding	1.4	2.7	0.8	2.9
Yield (t ha^{-1})				
Transplanting	1.38	1.39	1.54	1.45
Direct Seeding	0.57	0.37	1.19	0.55

Table 15. Use of water from DLD farm ponds in 2004 and 2005.

Parameters	2004	2005
Paddy production		
Paddy land holding (ha)	2.7	2.7
Transplanting area (ha)	2.3	2.1
Transplanting yield (t ha^{-1})	1.6	1.9
Direct seeding area (ha)	0.8	0.8
Direct seeding yield (t ha^{-1})	1.1	1.3
Methods of use	-	-
Pumping (%)	100	92
Manual pick up (%)	-	67
Benefit		
Paddy (Baht yr^{-1})	5200	6175
Fish (Baht yr^{-1})	600	812
Vegetables (Baht yr^{-1})	706	475
Fruit trees (Baht yr^{-1})	435	200
Animal drinking (frequency)	0	0
Domestic use (frequency)	37	73
Farmers' perception (%) to improve efficiency of farm ponds		
Indiscriminate use	100	46
Deepening of pond	38	31
Increase in pond size	8	-

Water harvesting: Table 15 shows the utilization pattern of farm ponds for various purposes, paddy production, monetary benefits and farmers' perception to improve the efficiency of farm ponds in 2004 and 2005. Higher monetary benefits were reported during 2005 in case of paddy cultivation and fishery (19 per cent and 35 per cent increase, respectively), while benefits in case of vegetables and fruits trees were higher during 2004.

Land use and crop intensification: Total cultivated area of Wang Chai watershed was 151 ha (942 rai), in 2005; it can be classified into eight land use pattern classes (Fig. 18). Paddy (47 per cent) and sugarcane (36 per cent) are major upland crops. Some additional area was brought under cultivation for paddy and sugarcane in 2005 due to availability of water. Pararubber is the new crop occupying 1 per cent and it replaced cassava in upland. Some of the farms with DLD farm ponds are classified as mixed farms (Figs. 18 and 19).

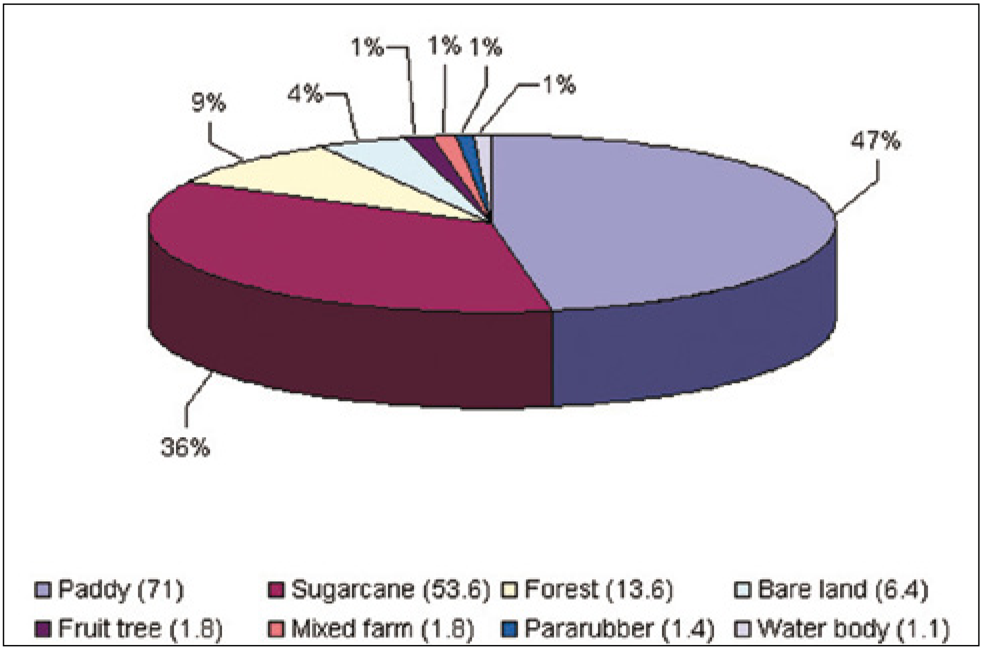

Figure 18. Land use pattern of Wang Chai watershed during 2005.

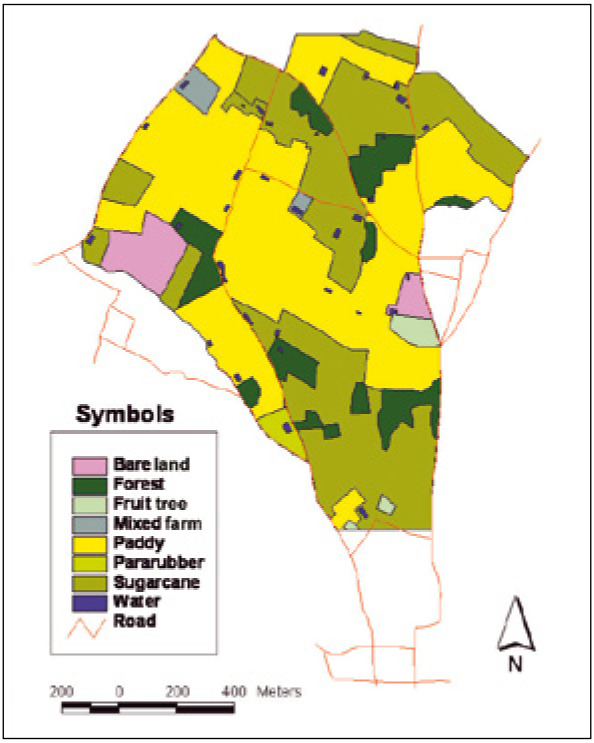

Figure 19. Land use in Wang Chai watershed in 2005.

Conclusion

In NE Thailand, lack of technological progress and increasing population pressure are taking a heavy toll on the productive resource base. Water scarcity, land degradation and productivity loss are becoming major challenges to the eradication of poverty, especially in the mountain areas of Thailand. Depletion of the resource base diminishes the capabilities of poor farmers and increases their vulnerabilities to drought and other natural calamities. Agriculture in NE Thailand is characterized by high risks from drought, degraded natural resources and pervasive poverty. For such rainfed areas, integrated watershed management could be a vehicle of development to conserve natural resources and to alleviate poverty.

In conclusion, the Tad Fa and Wang Chai watershed programs have made significant positive impacts on natural resources, rural livelihoods and environment. The science-led participatory watershed development through consortium and convergence approach minimized land degradation enhanced agricultural productivity and incomes decreased poverty of rural poor and improved the environment quality. The technical backstopping of watersheds by a consortium approach greatly enhanced the benefits of watershed program to the community. Some of the key learnings from these watersheds are:

- Consortium approach of various research and development organizations, and farmers has been very effective for increasing agricultural productivity and improving livelihoods.
- The integrated watershed program substantially increased productivity and augmented farm income. Some of the watershed activities such as cultivation of fruit trees were found highly successful in attaining the livelihood and environmental objectives of the watershed.
- Participatory planning with the community is found highly beneficial. Due to this the effectiveness and sustainability of various watershed interventions improved significantly.
- In most cases, it was found that the farmers come together for their immediate and private gains rather than only long-term and social gains.
- The formation of SHGs was found to be highly beneficial. Farmers were able to share information about crops, new technologies, and related problem and solution.
- A strong network of information is found necessary for increasing the effectiveness and sustainability of watershed program. In the changing economic regime, the technologies are changing rapidly and affecting competitiveness, markets, consumer preferences and prices.
- The concept of integrated watershed management is relatively new in Thailand. There is a need to address the second- and third-generation problems of integrated watershed management program.

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